I 49.66:158

COMPLETED
32

Techniques for Studying Nest Success of Ducks in Upland Habitats in the Prairie Pothole Region

IES
40
ORIGINAL

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE / RESOURCE PUBLICATION 158

BEST COPY AVAILABLE

RESOURCE PUBLICATIONS

This publication of the Fish and Wildlife Service is one of a series of semitechnical or instructional materials dealing with investigations related to wildlife and fish. Each is published as a separate paper. The Service distributes a limited number of these reports for the use of Federal and State agencies and cooperators. A list of recent issues appears on inside back cover.

Copies of this publication may be obtained from the Publications Unit, U.S. Fish and Wildlife Service, Matomic Building, Room 148, Washington, DC 20240, or may be purchased from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161.

Library of Congress Cataloging-in-Publication Data
Main entry under title:

Techniques for studying nest success of ducks in upland habitats in the prairie pothole region.

(Resource publication ; 158)
Supt. of Docs. no.: I 49.66:158
1. Ducks—Nests. 2. Ducks—Reproduction. 3. Bird populations—United States. 4. Bird populations—Canada. 5. Birds—United States—Nests. 6. Birds—Canada—Nests. I. Klett, Albert T. II. U.S. Fish and Wildlife Service. III. Series: Resource publication (U.S. Fish and Wildlife Service); 158.
S914.A3 no. 158 639.9'0973 s [598.4'1] 85-600335
[QL696.A52]

BEST COPY AVAILABLE

Techniques for Studying Nest Success of Ducks in Upland Habitats in the Prairie Pothole Region

By Albert T. Klett
Harold F. Duebbert
Craig A. Faanes
Kenneth F. Higgins

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Resource Publication 158
Washington, D. C. • 1986

BEST COPY AVAILABLE

I

Contents

	Page
Abstract	1
Equipment and Supplies	2
Choice of Vehicles	2
Nest Drags	2
Accessories for Data Collection	2
Nest Marking Supplies	2
Procedures for Nest Searches	3
Using the Cable-Chain Drag	3
Locating Nests	4
Marking Nest Locations	5
Determining the Stage of Incubation	5
Determining Fate of Nests	7
Successful Nests	7
Destroyed Nests	7
Abandoned Nests	8
Dead Embryos or Infertile Eggs	8
Considerations for Scheduling Nest Searches	9
Estimating Nest Success	10
Modifications of Mayfield's Method	11
Shortcut Method for Estimating Nest Success	13
Acknowledgments	13
References	13
Appendix A. Identifying Species From Evidence at Nests	15
Characteristics of Breast Feathers, Down, and Eggs	15
Key to Down and Breast Feathers	18
Appendix B. Instructions for Recording Data and Calculating Nest Success	20
Glossary	20
Sample Field Form for Recording Nesting Data	21
Computation of Nest Success	22

Techniques for Studying Nest Success of Ducks in Upland Habitats in the Prairie Pothole Region

By

Albert T. Klett and Harold F. Duebbert

U. S. Fish and Wildlife Service
Northern Prairie Wildlife Research Center
Jamestown, North Dakota 58402

Craig A. Faanes

U. S. Fish and Wildlife Service
School of Forest Resources
University of Georgia
Athens, Georgia 30602

and

Kenneth F. Higgins

U.S. Fish and Wildlife Service
South Dakota Cooperative Fish and Wildlife Research Unit
South Dakota State University
Brookings, South Dakota 57007-1696

Abstract

Selected procedures are described for conducting nesting studies of upland nesting ducks in the prairie pothole region. Emphasis is on the use of standard procedures so that comparable results can be obtained. Major topics addressed are finding nests by flushing hens with drags pulled by vehicles, recording of appropriate data, and calculating nest success rates. Techniques are described for conducting nest searches, candling eggs in the field, determining fate of clutches, and identifying species from evidence at nests. Two methods are presented for calculating nest success.

To assess the fate of nests of ducks in upland habitats over broad areas it is essential to obtain data on large numbers of nests. From 1969 to 1985, personnel at the Northern Prairie Wildlife Research Center (NPWRC) conducted duck nesting studies at many locations in the north-central United States and south-central Canada. During these studies, emphasis was on collecting samples of viable nests in upland habitat by flushing hens with cable-chain or chain drags pulled by all-terrain vehicles. Common upland nesters in the prairie pothole region include mallard (*Anas platyrhynchos*), gadwall (*A. strepera*), American wigeon (*A. americana*), green-winged teal (*A. crecca*), blue-winged teal (*A. discors*), northern shoveler (*A. clypeata*), northern pintail (*A. acuta*), and lesser scaup (*Aythya affinis*).

Most techniques used in these duck nesting studies have been described in published reports. While instructing many field assistants, however,

BEST COPY AVAILABLE

it became apparent that having a training manual containing selected techniques would be convenient. In addition, with increased use of nesting studies in waterfowl research and management in the prairie pothole region, investigators desired standardized procedures so that comparable results could be attained. Standardized procedures became especially important after newer and less-biased methods for computing nest success were developed (Mayfield 1961, 1975; Miller and Johnson 1978; Johnson 1979; Bart and Robson 1982).

We selected for this manual techniques that are effective and readily standardized. By using these techniques we were able to meet the objectives of a variety of research projects during a 15-year period. Because we recognize that there are other procedures that may be better suited for some studies, we have cited some alternatives, but have not described them in great detail.

This manual contains: (1) a description of methods for finding nests and marking their location; (2) identification of essential data and tips for collecting and recording them; (3) considerations for determining the number and dates of nest searches; and (4) a description of methods for calculating nest success.

We describe one way of obtaining and evaluating nesting data to estimate nest success. A discussion of study design is not included because the objectives of nesting studies vary widely and do not lend themselves to a "cookbook" treatment. There is a temptation to undertake nesting studies because nest success is an important component of recruitment, and nest characteristics can readily be measured. Unfortunately, many studies fail to meet their objectives because of poor design and inadequate samples. We cannot overemphasize the importance of preparing a sound study design before initiating nesting studies.

Equipment and Supplies

A list of equipment and supplies used for nesting studies conducted by NPWRC follows. Investigators can consider those items that would be useful for their own studies. The quantities listed are for one field crew.

Choice of Vehicles

Vehicles are used to tow nest drags. Where applicable, users should follow Government and Agency regulations concerning types of vehicles permitted and prescribed safety equipment such as seat belts, helmets, protective clothing, roll bars, and signs for slow-moving equipment.

1. Two four-wheel drive vehicles (4WD), preferably without cabs to ensure visibility. Vehicles of near equal weight and horsepower are important for providing similar pulling power through dense vegetation. They should be equipped with hitches for attaching drags, and tow bars if they are not driven between study areas. Care must be exercised in tall-grass habitats because of the fire hazard associated with catalytic converters on exhaust systems.
2. Two all-terrain cycles (ATC; three-wheel or four-wheel motorcycles, minimum size 105 cc) with reinforced hitches for towing drags. A special hitch extension is necessary to reduce the chance of the drag entangling in the rear tires.
3. Tractors have been used to tow nest drags but are unstable on steep terrain, are difficult to move between distant study areas, and cause excessive disturbance to cover.

Nest Drags

1. One 53-m cable-chain drag (*see* Higgins et al. 1977 for construction details) or 61-m (9.5-mm-diameter) chain drag to be towed by 4WD's.
2. One 30.4-m (8-mm-diameter) chain drag to be towed by ATC's. (Chain drags can be used in lengths that are suitable for roadsides or other narrow or small areas.)
3. Supplies needed to use and maintain drags are basic tools, chain hooks, chain repair links, and leather-faced gloves.

Accessories for Data Collection

1. Three or more candling tubes.
2. Two pairs of binoculars.
3. Field forms with instructions in notebooks.
4. Photos (preferred) or field maps for plotting nest locations.

Nest Marking Supplies

1. Marking materials such as wire flags, willow sticks, flagging tape, spray paint. Nest markers should be flexible so they will not break when the drag passes over them on subsequent searches.
2. Large screwdriver or pointed tool to make holes in hard ground for nest markers.
3. Waterproof ink pens.

BEST COPY AVAILABLE

4. Compass (optional).
5. Canvas bags for carrying supplies and data notebooks.

Procedures for Nest Searches

Using the Cable-Chain Drag

The cable-chain drag (Higgins et al. 1969, 1977) was developed by biologists to locate duck nests in grassland habitat. Some investigators use a single 61-m (9.5-mm-diameter) chain instead of the cable-chain drag. The relative flushing efficiency of the two drags has not been tested. Most investigators believe the cable-chain drag is more efficient in dense, herbaceous cover, and some consider it useful as a standard method when comparing nest densities. Others prefer the chain drag because it is easier to maintain, covers a larger area per sweep, and is less likely to tangle or to hang up on obstacles than the cable-chain drag. Drags pulled by vehicles are most effective in grassland, cropland, and short brush such as *Symphoricarpos* sp. Areas of tall brush and trees or wetlands must be searched by walking or wading. Hand-pulled rope drags with cans or sections of chain attached can be used when access with vehicles is not feasible (e.g., where crops are growing). Trained dogs are often used to help find nests.

Two drivers and a spotter are used to locate nests with the cable-chain drag (Fig. 1). The need for a spotter is essential when searching tall dense cover. Preferably, the crew leader (also the recorder) should drive the vehicle on the left, accompanied by the spotter. Some studies require repeated searches of the same field during a nesting season. Best results are obtained when the subsequent searches are conducted by the same persons in the same positions as on previous searches. This enables better recall of nest locations if the marker was lost or when the nest location was not recorded accurately.

Before starting a nest search, the investigator should map the permanent features of each field. The direction of travel should be determined after

Fig. 1. A crew of two drivers and a spotter search for ducks nests with a cable-chain drag.

BEST COPY AVAILABLE

scouting the shape and topography of the cover block and locating such obstacles as boundary fences, wetlands, and tree plantings (Fig. 2). Usually, the search should begin parallel to the longest straight field edge.

To start a search, the drag is stretched between the vehicles and all twists and entanglements are removed. While dragging, it is essential that each driver maintain proper alignment and distance relative to the other vehicle. Improper alignment (Fig. 3) occurs when one vehicle gets too far ahead or too close to the other. The distance between vehicles can be adjusted by slowing down or stopping to allow the other driver to resume the proper interval. Both drivers should watch along the drag as much as possible and still maintain a straight course in the field. The ability to do both simultaneously diminishes greatly as vehicle speed increases. Search speeds should be held between 3 and 10 km/h.

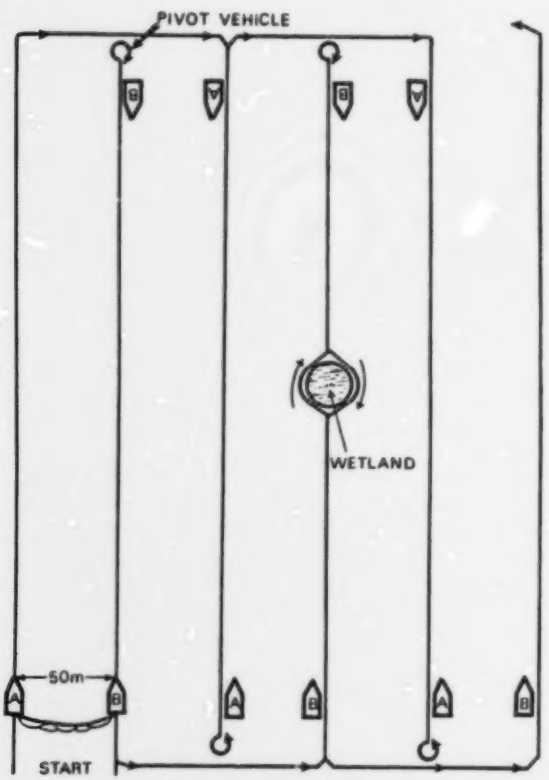


Fig. 2. Diagrammatic search pattern of a hypothetical field (Higgins et al. 1977).

When the dragging units approach the end of the field, the inside or pivot driver should slow down until the other driver enters the turn, causing the cable chain to go slack. Then the pivot driver makes a U-turn and waits in the back track until the other vehicle has attained the proper interval and alignment (Fig. 2).

Both drivers and the spotter must be constantly alert for twists or entanglements in the cable-chain drag. Twists most commonly occur during turns at the end of a field, or after the drag has flipped over a rock, tall shrub, or other obstacle. Twists can usually be corrected by untangling the chains; it is not usually necessary to remove the cable from the vehicles. Wire, dead brush, or other debris caught in the drag should be removed immediately to avoid damaging eggs.

The drivers are responsible for species identification when the hen flushes. Major distinguishing features are the size of the hen and the arrangement and contrast of dark and light colors of the plumage, especially on the wings and tail. The waterfowl identification guides *Ducks at a Distance* (Hines 1978) and *Waterfowl Identification in the Central Flyway* (Central Flyway Waterfowl Council 1974), provide illustrations showing these key characteristics. If in-flight identification of the hen is not made, the species can usually be determined at the nest from the size and color of eggs, down, or breast feathers (*see* Appendix A).

Locating Nests

The spotter's main job is to constantly watch the drag for flushing birds. When a bird flushes, the spotter must mentally mark the site and keep his eyes on it while guiding one of the designated drivers to the flushing location. To do this requires strict discipline; the spotter must avoid the tendency to follow the flight of the bird. Marking the flushing location is aided by noting nearby plants, rocks, or other landmarks. If both vehicles immediately stop when a bird flushes, the nest will usually be close to the drag. Drivers must avoid sudden stops that distract the spotter. If a driver has marked a flushed bird, he should remain in the vehicle and assist the spotter in guiding the other driver to the site. The spotter and one driver should not leave their vehicles until the nest is found.

Only one person should visit the nest unless more persons are required for habitat measurements.

BEST COPY AVAILABLE

The recorder should avoid excessive disturbance of the vegetation that might attract predators. Care should be taken to avoid stepping on well-concealed nests. It is wise to not take a step until the ground is carefully inspected.

Nests can usually be found by following vocal and hand-signal directions from the spotter. Hens without nests might be flushed while they are selecting nest sites or digging scrapes. If a nest cannot be found after a reasonable effort, the approximate flushing site should be marked with a flag so that the area can be searched again on foot on another day. This procedure reduces the amount of trampled vegetation around nests. If the bird does not flush during the second visit, the marker should be removed and no further effort made to find the nest.

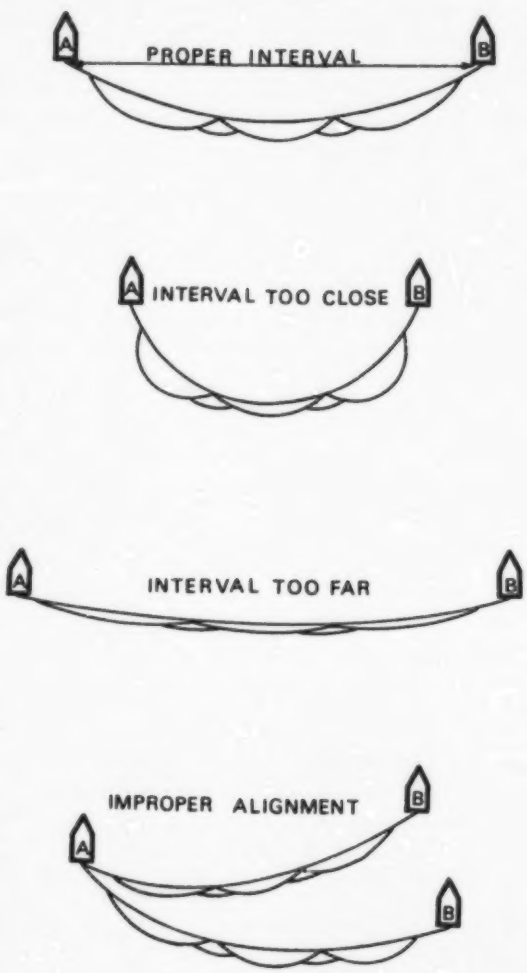


Fig. 3. Examples of proper and improper interval and alignment while towing a cable-chain drag in field searches (Higgins et al. 1977).

Marking Nest Locations

After recording the necessary nest data, the recorder covers the eggs with down and other nest material to conceal them from avian predators. To determine if investigator disturbance has caused nest abandonment, some workers place a small object, such as a strip of yarn, over the covered nest in such a way that its disarrangement by a returning hen can be detected on a subsequent visit.

Slender willow stakes flagged with short strips of cloth or fluorescent tape are recommended for marking nest sites so they can be relocated. Stakes should be long enough to stand above anticipated vegetative growth. Wire survey flags can be used in short cover.

Stakes should be firmly anchored at least 15 cm into the soil, at a standard distance (4 m is recommended) and direction from the nest. Nest identification numbers should be recorded with waterproof ink on the stake or flag. Care should be taken to write the same number on the nest marker as on the nest record form.

The exact location of all nests should be plotted on a map or aerial photo. Landmarks such as rock piles, wetlands, brush clumps, fences, and other landscape features should be used for referencing nest locations. Compass directions and measured distances from nests to natural features are useful in pastures because cattle are attracted by conspicuous nest markers and often dislodge flagged stakes. To aid in relocating nests, number and map the drag strips.

Determining the Stage of Incubation

Incubation stage of duck eggs is used to determine when laying and incubation began and to estimate hatching dates. These parameters are used to calculate nest success. The field candling method described by Weller (1956) is convenient for upland nesting ducks and is the one we used in our studies. Training, however, is necessary to

obtain reliable data. Westerskov (1950) described a flotation method for determining the stage of incubation of ring-necked pheasant (*Phasianus colchicus*) and gray partridge (*Perdix perdix*) eggs. The decreasing specific gravity of eggs during incubation changes their orientation and buoyancy when floated in water. Inexperienced investigators can use the flotation method as a guide until they gain competence with the Weller method. They can also compare their estimates of embryo development with the eggs of a known incubation stage. This training method is very good when nests are found during the egg-laying stage and later checked during incubation.

For the Weller candling method, rubber radiator hose (15–20 cm long; 3.8 cm ID) is used as a candler. We recommend wrapping fluorescent adhesive tape around the tube to help find it if misplaced in dense vegetation. On bright days candling efficiency can be increased by holding the tube slightly above the horizontal axis (Fig. 4). The egg should be held vertically, with the larger end toward the top, and rotated slowly to obtain a view from all sides. This method can be used during days with heavy overcasts. At least two eggs from each clutch should be candled.

Weller (1956) described five criteria for age classification: (1) size of the embryo when visible, (2) shape and appearance of the yolk, (3) development of the extra-embryonic circulatory system, (4) density of the opaque areas, and (5) size of the air cell. Weller described the development of redhead (Aythya americana) embryos as follows (*see also* Fig. 5):

Fig. 4. Proper positioning of a duck egg for field candling (Higgins et al. 1977) is demonstrated.

1. *Unincubated.* The yolk is barely visible due to its pale yellow color. It is free floating and the air cell is quite small. In unincubated eggs that have been deserted by the female, the yolk soon adheres to the shell membrane and turns brown.
2. *Four days.* The embryo and the extra-embryonic vascular system are clearly visible and red in color (the "spider" stage of the poultryman). The yolk is yellow orange and less solid than in the fresh egg. The margin of area vasculosa, the sinus terminalis, is often visible.
3. *Eight days.* The outline of the embryo is less distinct, appearing as two isolated dark areas. These are the head and the trunk; the thin neck is barely visible. A rocking motion of the embryo may be seen at this time but is retarded by handling. The yolk now appears to be more solid because it has been enveloped by the yolk sac and, in the side view, the sinus terminalis is distinct; its margin may parallel the long axis of the egg or may be diagonal.
4. *Twelve days.* The yolk sac has completely enclosed the yolk except for a small area opposite the embryo where the albumen is attached. The vascularization causes an increased density and less distinct outline of the yolk mass. The growth of the embryo forces the remaining yolk into two lobes, one lying on either side of the duckling. The most opaque areas outline these lobes where they are pressed against the shell. The embryo is indistinctly visible as a dark area isolated from the yolk.
5. *Sixteen days.* When seen from the rear view, this stage differs from that of the 12-day stage in that the light band separating the embryo and the yolk mass is much narrower due to an obvious increase in the size and opacity of the embryo. The air cell is noticeably larger than in the 12-day stage.
6. *Twenty days.* The egg is now opaque except for the air cell and the area immediately adjacent, plus a minute area at the small end. The lobes of the yolk mass are barely discernible.
7. *Twenty-two days.* The bill of the duckling is now pressed against the inner shell membrane and is visible as a projection in the air cell.
8. In embryos that die before hatching, the blood vessels and yolk appear brown. The observer will learn to distinguish these with practice.

BEST COPY AVAILABLE

Weller's criteria for redhead eggs have been modified slightly for use with other species of ducks. The stages of incubation do not vary appreciably among species through the first 12 days, but some species differ from the redhead during later stages (Fig. 5).

Determining Fate of Nests

Successful Nests

We define a successful nest as one in which at least one egg hatched. The presence of detached shell membranes (Fig. 6) is the best evidence that eggs hatched (Girard 1939). Shell membranes of eggs that are broken during laying or incubation remain firmly attached to the inside of the shell. Other evidence of hatching is the presence of yellowish feather sheaths or small shell fragments without membranes in the nest material.

Detached membranes are not always as conspicuous as shown in the figure; they are often compressed and matted together at the bottom of the nest bowl and may be covered or mixed with egg fragments, nest debris, and down. Membranes are often enclosed by others—something to consider if there is a need to know the number of eggs that hatched. Careful observation and judgment are necessary to correctly determine the fate of successful nests that may have been disturbed by predators or rodents or machinery after the eggs hatched. Sometimes mice or ground squirrels eat or remove some of the membranes. Nests should be visited as soon as possible after the estimated hatch date to better judge nest fate and the number of eggs that hatched.

Destroyed Nests

Nest failure can usually be attributed to predation, farming operations, flooding, or livestock, but sometimes the direct cause cannot be determined. Observer judgment is usually necessary. The appearance of the eggs and the amount of disturbance at the nest vary considerably among destroyed nests. Eggs may be intact, as in flooded nests; more often they are broken and scattered.

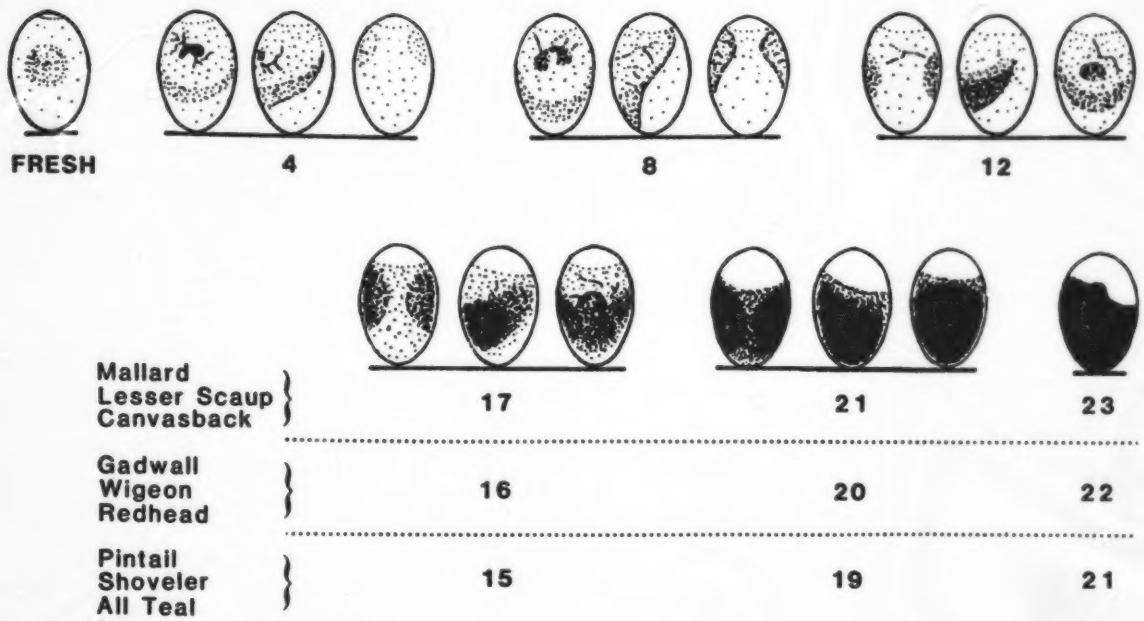


Fig. 5. Characteristics of duck eggs candled during different stages of incubation (numerals denote days). When three views are shown, they are (left to right) front view with embryo adjacent to the viewer, side view, and rear view (adapted from Weller 1956).

BEST COPY AVAILABLE

Predators may remove some or all of the eggs without leaving fragments or disturbing the nest material. Investigators should be aware of predator species on their study areas. In many situations, the identification of predators on the basis of egg remains and nest debris is not reliable. Sometimes more than one predatory species is responsible.

Abandoned Nests

Nests are sometimes abandoned, especially when hens are disturbed during early stages of laying (one to three eggs). Abandoned nests are those containing undisturbed clutches that are no longer tended by a hen. It is usually impossible to determine if a clutch was actually abandoned by a surviving hen or if the nest was untended because the hen was injured or killed. Hens sometimes take extended recesses during incubation and their eggs, especially during cool and wet weather, may feel cool when handled. Nests that are suspected of being abandoned should be revisited to verify their fate.

Dead Embryos or Infertile Eggs

In some clutches, all of the eggs are infertile or contain dead embryos. When this occurs, hens may continue to incubate after the time of normal hatching. When candled, infertile eggs appear "clear" and those in which the embryo died at an early age have black blotches attached to the inside of the shell. When embryos die after some

Fig. 6. Detached membranes are visible in these hatched eggs.

BEST COPY AVAILABLE

development, the blood vessels and yolk appear brown (Weller 1956).

Considerations for Scheduling Nest Searches

Duck nesting activity spans about 4 months in the northern prairie States. Mallards and northern pintails start laying in early April and the nesting period of some species, especially the gadwall, may extend into early August in years when wetland conditions are favorable. Considerations when planning search schedules include study objectives, nesting chronology (especially peaks in nesting activity), and manpower and other resource limitations.

Nesting chronology varies by species, locality, and year. Data from previous studies in your local area may provide useful guidelines for scheduling searches. For example, data in Table 1 portray the relative efficiency of varied search numbers and schedules for finding nests with a cable-chain drag on a 250-ha study area in south-central North Dakota in 1976. A total of 523 duck nests of five upland nesting species were found during 12 searches conducted at weekly intervals. Each entry shows the percentage of all nests found—for three species or all species combined—with a specific search schedule.

Results of this study indicated that if only a single search could be made, late May would be the optimal time for locating nests of mallard, blue-winged teal, and all species combined. A single search in mid-June would be optimal for locating gadwall nests. Wetland conditions in June 1976 were poor and relatively few nests were found during the early July search.

The number of additional nests found per search decreases with each new search. For some studies this would indicate that it would be more efficient to conduct one or two searches in each of a larger number of similar habitats than to search fewer

Table 1. *Percent of nests found in south-central North Dakota in 1976 using varying numbers and timing of search schedules.*[a]

Search Number[b]	Nests found (% of total)			
	Mallard	Gadwall	BW-teal	5 Species[c]
3	28	00	03	13
6	28	11	48	36
9	19	35	21	20
12	04	18	01	04
3-6	53	11	50	48
4-8	47	49	53	51
5-9	36	35	52	44
6-10	39	47	55	47
7-11	27	56	42	38
3-6-9	64	44	64	61
4-7-10	50	56	57	56
5-8-11	45	69	63	56
6-9-12	42	56	63	53
1-4-7-10	54	56	57	56
2-5-8-11	62	69	63	64
3-6-9-12	67	56	54	64
2-4-6-8-10-12	77	87	82	82
Total nests found (12 searches)	135	56	225	523

[a] Unpublished data, NPWRC.

[b] 1 = 19–20 April, 2 = 27–29 April, 3 = 3–6 May, 4 = 10–12 May, 5 = 17–20 May, 6 = 24–28 May, 7 = 1–4 June, 8 = 7–11 June, 9 = 14–18 June, 10 = 21–25 June, 11 = 28–30 June, 12 = 7–9 July.

[c] Mallard, gadwall, blue-winged teal, northern shoveler, northern pintail.

BEST COPY AVAILABLE

units many times. An advantage of multiple searches is that larger samples of nests of all species can be found in habitat units of special interest. Searches conducted at regular intervals throughout the nesting season also increase the probability of including variation in mortality related to seasonal effects. Again, we emphasize that the search schedule is part of the study design and depends on the study objectives.

If nest success rates are to be compared we recommend that the same search schedule be used for each habitat unit. (Sample size considerations are presented on page 12.)

A recommended search schedule for monitoring nest success in south-central North Dakota is three searches at 3-week intervals starting the first week in May (Table 1, searches 3-6-9). In 1976 the sample of nests found with this schedule included 61% of the total nests found with 12 searches. When prolonged nesting activity occurs during years of favorable wetland conditions, an additional search in late June or early July is recommended.

The amount of nesting cover that can be searched in a day should also be considered. The area that can be searched by a drag crew depends on the cover type, terrain, and number of nests found. Usually a 65-ha tract of herbaceous nesting cover can be searched with a cable-chain in about 4 or 5 h. When practical, searches should be completed by noon because laying hens are more likely found on the nest in the morning hours.

Estimating Nest Success

A purpose of most duck nesting studies is to obtain an estimate of nest success, the probability (P) that a nesting attempt will result in production of one or more ducklings. In the past, nest success was calculated as the percentage of observed nesting attempts that were successful. This estimator (P_1), referred to as apparent nest success, is

$$P_1 = N_s/(N_s + N_u) \qquad (1)$$

where N_s and N_u are the observed numbers of successful and unsuccessful nests, respectively. This method is appropriate provided that successful and unsuccessful nests are discovered with equal probability, a condition that may be met in studies of artificial nesting structures, small islands, or other small units of habitat that can be intensively searched for terminated nests.

Apparent nest success estimates are biased when applied to samples of clutches gathered by flushing hens from their nests. The age of these clutches at discovery can range from newly initiated (one egg) to late incubation. Advanced clutches are more likely to hatch than young clutches because of the shorter interval between discovery and hatching.

To illustrate this concept, consider a population of mallard nests with a constant daily survival rate (s) of 0.96. The probability of a clutch surviving 1 day is 0.96; 2 days, 0.922 (0.96×0.96 or 0.96^2); 3 days, 0.885 ($0.96 \times 0.96 \times 0.96$ or 0.96^3), and so on. If the mean laying period plus incubation period of successful clutches (h) is 35 days, the probability of hatching (P) for a clutch found on the day it was initiated is

$$P = s^h \qquad (2)$$
$$P_{35} = 0.96^{35} = 0.2396.$$

The probability of hatching for clutches found 5 days after initiation is

$$P_{30} = 0.96^{30} = 0.2939,$$

because they have already survived 5 days and need to survive only 30 additional days to hatch. With a daily survival rate of 0.96, the probability of hatching for clutches found at various ages is:

Age found (days)	Probability of hatching (apparent nest success)	Bias
0	$0.96^{35} = 0.24$	0.00
5	$0.96^{30} = 0.29$	+0.05
10	$0.96^{25} = 0.36$	+0.12
15	$0.96^{20} = 0.44$	+0.20
20	$0.96^{15} = 0.54$	+0.30
25	$0.96^{10} = 0.66$	+0.42
30	$0.96^{5} = 0.82$	+0.58
34	$0.96^{1} = 0.96$	+0.72

Apparent nest success, applied to a sample of active nests, reflects the true success rate only when all clutches are found on the day they were initiated. Apparent success overestimates true success when clutches are found at a later date.

To overcome the bias in apparent success rates, Mayfield (1961, 1975) estimated daily survival for the interval that nests were exposed to risk while under observation and used it to estimate nest success from Eq. 2. The exposure interval (in days) for each nest begins on the day the nest was found and ends on the day eggs hatched or the clutch was destroyed or abandoned or was no longer under observation. When the day of destruction or abandonment is unknown, it is assumed to have occurred midway between the last two visits. For nests observed on 2 or more days but not revisited to determine their fate, the day of the last visit marks the end of the exposure interval. From a group of nests the daily mortality rate (m) is estimated by the number of nesting attempts that failed divided by the number of exposure days. The daily survival rate (s) is the complement of m, or $s = 1-m$, and the Mayfield estimator of nest success (P_s) from Eq. 2 is

$$P_s = s^h = (1 - N_o/E)^h \qquad (3)$$

where E is the total number of exposure days. A basic assumption of the method is that the daily survival rate for the intervals that nests were under observation is the same for all nests and all intervals. This method has gained acceptance by ornithologists. Miller and Johnson (1978) and Johnson (1979) suggested modifications in the calculation of exposure days that improved the method for use in duck nesting studies. Johnson (1979) and Bart and Robson (1982) described a maximum likelihood estimator that is more appropriate when nests are visited periodically and the day nesting attempts fail is unknown. However, computations are difficult and use of a computer is advised. Johnson and Klett (1985) described a method for obtaining quick estimates of duck nest success that is a special application of the maximum likelihood method.

In the following sections we summarize some standard procedures that have been used to estimate success rates for samples of duck nests that were found by flushing hens from their nests. In doing so we repeat this caution by Mayfield (1975): "...we should be wary of being lured into a fictitious appearance of precision. Any method we use will give no more than an approximation of the truth, and this method merely helps avoid certain gross errors that are common."

Modifications of Mayfield's Method

One minor modification in Mayfield's method for calculating exposure days uses the estimated hatch date to determine exposure days for successful nests and help define the interval during which a nest was lost. Another modification involves calculating exposure when the intervals between nest visits are long.

We present a formula for the standard error of the Mayfield estimator with which confidence limits can be constructed for use in estimation and hypothetical testing.

Essential Data

A standard form is recommended for recording data in the field (a sample form with instructions appears in Appendix B). The format may vary, but it should be designed for ease in summarizing the data either manually or by computer. Space should be provided to record the species of duck (A.O.U. number, *see* Appendix Table B-1), a unique nest identification number, and the full clutch size (when known). Essential data recorded each time a nest is inspected are the date, number of eggs and their stage of incubation, and clutch status (still viable; eggs hatched, abandoned, or destroyed; or unknown). Space should also be provided for identifying nests that are not used in calculating success. Examples are clutches that had hatched or were partially or totally destroyed before they were found, and clutches that were destroyed or abandoned because of searching activities on the day they were found. Data from these nests may be useful for other purposes, but are not used to compute nest success.

Calculations

All calculations can be made on an inexpensive hand-held calculator with the capability to take the root value of any positive number or raise any positive number to any power.

Mayfield nest success estimates (P_s) are calculated from Eq. 3. Mean ages of clutches at hatching (h) are presented in Appendix Table B-1.

The exposure period is usually the number of days between the date a nest was discovered and the date it was terminated either successfully or unsuccessfully. It is legitimate, however, to use known periods of nest survival observed between

nest visits even if the fate of the nest is not determined, or if the nest fails because of investigator disturbance some days after the nest was found.

Exposure for successful clutches is the number of days between discovery and the estimated hatch date. The hatch date can be estimated from the age of the clutch when found, determined by candling, and the mean age of clutches at hatching. The date on which a nesting attempt fails is usually unknown unless the nest is visited daily. The date on which a clutch is abandoned can sometimes be determined by noting changes in the number of eggs or stage of incubation since the last visit. When the exact date on which a clutch is destroyed or abandoned is unknown, exposure days are derived from two sources: *known exposure*—the number of days between two visits that the clutch was known to survive, and *probable exposure*—a percentage of the interval during which the clutch was known to have been destroyed or abandoned. To estimate probable exposure for short intervals (<15 days), we assume that the clutch survived half of the interval between the last two visits when the last visit (date fate was determined by the investigator) occurs before the estimated hatch date. When fate was determined after the estimated hatch date, we assume the clutch survived half of the interval between the preceding visit and the estimated hatch date.

In actuality the expected date of loss is dependent on the daily survival rate and the length of the interval during which the loss occurred. Johnson (1979) presented a formula for the probable exposure of a destroyed nest. For moderate values of s, the midpoint assumption was reasonable up to about 15 days but overestimated probable exposure when the interval was longer (as is often the practice in waterfowl nesting studies). For intervals longer than 15 days, 40% of the interval was a more reasonable approximation of probable exposure. Because the expected days at risk are difficult to calculate we recommend using 50% of intervals <5 days and 40% of longer intervals as an estimate of probable exposure.

Detailed instructions for computing nesting success by the modified Mayfield method are presented in Appendix Table B-3.

If desired, the variance (v) and standard error (SE) can be approximated for the estimator (s) of daily survival (Johnson 1979):

$$v = (s)(m)/E$$
$$\text{SE} = \sqrt{v}$$

The standard error can be used to obtain confidence intervals for s (95% CI = $s \pm 2$ SE) and to compare daily survival rates of two samples of nests. Confidence limits for s can be used to establish approximate limits for nest success by raising them to a power equal to h (mean age of clutches at hatching, Appendix Table B-1). It should be noted that confidence limits for nest success are asymmetrical because they are derived exponentially.

Because of this exponential relation, minor changes in v generate major changes in the width of the confidence interval for nest success. An increase in the number of exposure days in the sample of nests will decrease the variance and hence, narrow the confidence interval. For studies designed to obtain precise estimates of nest success, (e.g., within homogeneous habitat units), we recommend a minimum of 750 exposure days. On the basis of previous information on the expected range of daily survival rates and exposure days in samples of nests, we believe this goal should be reached with a sample of 50 to 75 nests. Smaller confidence intervals can be obtained if investigators are willing to accept lower confidence levels, such as 90% or even 80%. For those interested in details of sample size requirements, Bart and Robson (1982) present formulas for obtaining specified precision on single estimates and for estimating differences between two populations.

Advantages and Limitations

The modification of Mayfield's method presented here is appropriate with samples of nests that were active when found. An important assumption is that the clutch survival rate is constant from day to day. Johnson (1979) reported that the bias introduced by variation in daily survival rates is slight unless the variation is extreme. Klett and Johnson (1982) found that nest success rates were overestimated (by as much as 13%) when daily survival rates are much lower during the early stages of laying than during incubation, and they suggested a method for correcting this bias. Bart and Robson (1982) described a method for checking the assumption of constant survivorship. Large samples of nests, however, are required.

The assumption that all nests are subject to the same mortality is obviously violated when short-term catastrophic events caused by farming practices (e.g., tillage or mowing) or weather (e.g.,

BEST COPY AVAILABLE

heavy snowfall, hail, or flooding) occur. Nests that were expected to hatch before or were initiated after the event would likely have different hatch rates from those subject to the event. In most studies samples are not large enough to estimate overall nest success by partitioning the sample into subsamples affected by or not affected by the event.

Some of the advantages of the modified Mayfield method are: (1) it provides survival rates that are less biased than apparent rates for samples of clutches that are active when found, (2) the calculations are not as complicated as the maximum likelihood method, (3) it is robust in regard to moderate variation in daily survival rates, and (4) estimated standard errors are available for setting confidence intervals and testing for statistical differences in survival rates.

Shortcut Method for Estimating Nest Success

Essential Data

For each nest, only species identification, age when found, and ultimate fate are needed to estimate nest success rates by this method (Johnson and Klett 1985). With two exceptions the same nest records are used to calculate both the Mayfield and shortcut estimator of nest success. When the shortcut method is used all nests of unknown fate and all nests that were damaged by investigators or were abandoned because of investigator disturbance are excluded. These nests are used in the Mayfield calculations if the known component of exposure is >0.

Calculations

The same assumptions used for the Mayfield method apply to the shortcut method. We denote by h the mean age at which hatching occurs (Appendix Table B-1), and by f the mean age of clutches when found. If all the nests are found at age f, then apparent nest success (Eq. 1) is the percentage of nests that survived the interval $h-f$ and the daily survival rate for that interval is the $h-f$ root of apparent nest success.

$$s = \sqrt[h-f]{\text{apparent nest success}}$$

or

$$s = [N_s/(N_s + N_u)]^{1/(h-f)} \qquad (4)$$

The shortcut estimator of nest success (P_3) is then calculated from Eq. 2. In this special case (all of the nests are found at age f), s provides the maximum likelihood estimate of the daily survival rate (Bart and Robson 1982). The result is only approximate when actual ages vary and f is the mean age when found.

Detailed instructions for computing nest success by the shortcut method are presented in Appendix Table B-3.

Advantages and Limitations

The shortcut estimator requires minimal information for each nest and is easy to compute. The method is useful for quick estimates and is recommended for preliminary analyses or to check the calculations of the Mayfield estimator. Because the shortcut estimator is an approximation of the Mayfield and maximum likelihood estimator and is not useful for statistical evaluation, we recommend that the last two methods be used whenever possible.

Acknowledgments

We thank the personnel of NPWRC and the Central Flyway Recruitment Study Team for their suggestions for this manual and for their reviews of earlier drafts of the original loose-leaf version used in 1983. Among them we especially thank Douglas Johnson and Terry Shaffer. We are also grateful to Tammy Sharp and Judy Harr for typing the manuscript; Dave Fellows, Bob Woodward, and Ray Thielman for preparing the figures; Mavis Meyer for designing the cover illustration; and Don Sparling for his editorial assistance.

References

American Ornithologists' Union. 1983. Check-list of North American birds. 6th edition. Allen Press, Lawrence, Kans. 877 pp.

Bart, J., and D. S. Robson. 1982. Estimating survivorship when the subjects are visited periodically. Ecology 63:1078-1090.

Bellrose, F. C. 1976. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, Pa. 544 p.

Broley, J. 1950. Identifying nests of the Anatidae of the Canadian prairies. J. Wildl. Manage. 14:452-456.

Central Flyway Waterfowl Council. 1974. Waterfowl identification in the Central Flyway. Central Flyway Waterfowl Council. 51 pp.

Girard, G. L. 1939. Life history of the shoveler. Trans. N. Am. Wildl. Conf. 4:364-371.

Higgins, K. F., L. M. Kirsch, and I. J. Ball, Jr. 1969. A cable-chain device for locating duck nests. J. Wildl. Manage. 33:1009-1011.

Higgins, K. F., L. M. Kirsch, H. F. Duebbert, A. T. Klett, J. T. Lokemoen, H. W. Miller, and A. D. Kruse. 1977. Construction and operation of cable-chain drag for nest searches. U. S. Fish Wildl. Serv., Wildl. Leafl. 512. 14 pp.

Hines, B. 1978. Ducks at a distance. U. S. Department of the Interior, Fish and Wildlife Service. Available from: Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 56 pp.

Johnson, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651-661.

Johnson, D. H., and A. T. Klett. 1985. Quick estimates of success rates of duck nests. Wildl. Soc. Bull. 13:51-53.

Klett, A. T., and D. H. Johnson. 1982. Variability in nest survival rates and implications to nesting studies. Auk 99:77-87.

Mayfield, H. 1961. Nesting success calculated from exposure. Wilson Bull. 73:255-261.

Mayfield, H. 1975. Suggestions for calculating nest success. Wilson Bull. 87:456-466.

Miller, H. W., and D. H. Johnson. 1978. Interpreting the results of nesting studies. J. Wildl. Manage. 42:471-476.

Weller, M. W. 1956. A simple field candler for waterfowl eggs. J. Wildl. Manage. 20:111-113.

Westerskov, K. 1950. Methods for determining the age of game bird eggs. J. Wildl. Manage. 14:56-67.

Appendix A

Identifying Species from Evidence at Nests

With experience it is possible to identify a species from the characteristics of down and breast feathers in nests (Broley 1950). Size and color of eggs, although variable, provide additional evidence, as does the size of the nest bowl. Mean egg sizes (Bellrose 1976) are:

Canvasback	63.7 × 44.6 mm
Redhead	60.2 × 43.4 mm
Mallard	57.8 × 41.6 mm
Scaup	57.0 × 39.4 mm
Gadwall	55.3 × 39.7 mm
American wigeon	53.9 × 38.3 mm
Northern pintail	53.6 × 38.2 mm
Northern shoveler	52.2 × 37.0 mm
Blue-winged teal	47.1 × 33.9 mm
Green-winged teal	45.8 × 34.2 mm

Evidence at nests should only be used to verify species identification when nests are found by methods that flush the hens. Species identification from evidence at nests is necessary in studies that include nests found after the eggs hatched or were destroyed or abandoned.

Certain characteristics are specific to the down and breast feathers and the eggs of each species, but considerable individual variation occurs, especially among breast feathers. By looking at several feathers in each nest it is often possible to find "key" breast feathers that permit positive species identification. However, key feathers may be absent or the presence of other body feathers may cause confusion. A reference sample of breast feathers and down taken from correctly identified nests can be very useful. Feathers should be collected from several nests of each species to depict the wide range of intraspecific variation.

Key points to note in breast feathers include relative size, coloration, and patterns between dark and light tones (Fig. A–1). The same principles apply to the down. Breast feathers can be identified more reliably than down but the size and color of down feathers or eggs often provide additional evidence.

Characteristics of Breast Feathers, Down, and Eggs

Descriptions of the breast feathers, down, and eggs of ground-nesting ducks commonly found in the prairie pothole region follow. Species that might easily be confused are grouped together. Generally, dabbling ducks and lesser scaup are the primary upland nesters, but redheads and canvasbacks (*Aythya valisineria*) occasionally nest in upland cover.

Mallard

Breast feathers of mallards are relatively larger than those of other ducks described. The central area is brown and extends in a broad pattern to the tip of the feather. Usually a suggestion of a cross or mottling is noted in the feather pattern. Distal margins are distinctly cinnamon colored. The northern shoveler also regularly has definite cinnamon coloration on the breast feathers, but the brown central area ("spot") does not extend to the tip. Mallard breast feather patterns vary considerably. Down feathers are light brown with a white center and little or no frosting on the tips. Eggs are larger than those of other dabbling ducks described and are usually pale olive buff or various shades of brown.

Northern Pintail

A typical breast feather pattern has a dark brown base extending in a narrow, well-defined strip to the distal tip of the feather. The lateral margins of this brown strip are light tan (Fig. A–1). This pattern is similar on mallard feathers, except that the margins are cinnamon colored on mallard feathers. Northern pintails and mallards are the two dabbling ducks that have a brown central stripe extending to the tip of the breast feather. Down feathers are brown and small in relation to the size of the hen. Egg color varies from greenish yellow to gray green.

Northern Shoveler

Many observers believe this is the easiest species to identify from breast feathers. The

BEST COPY AVAILABLE

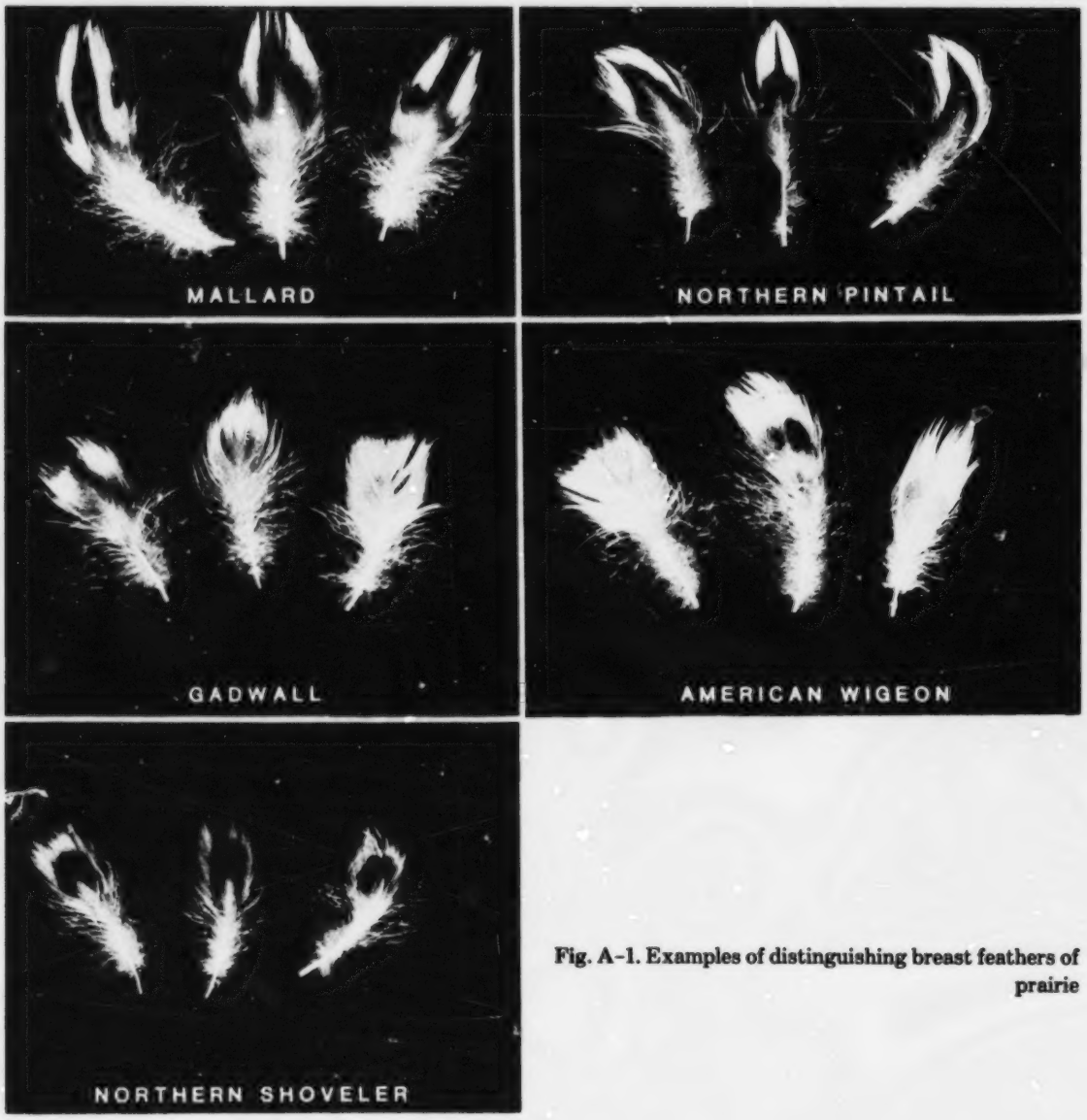
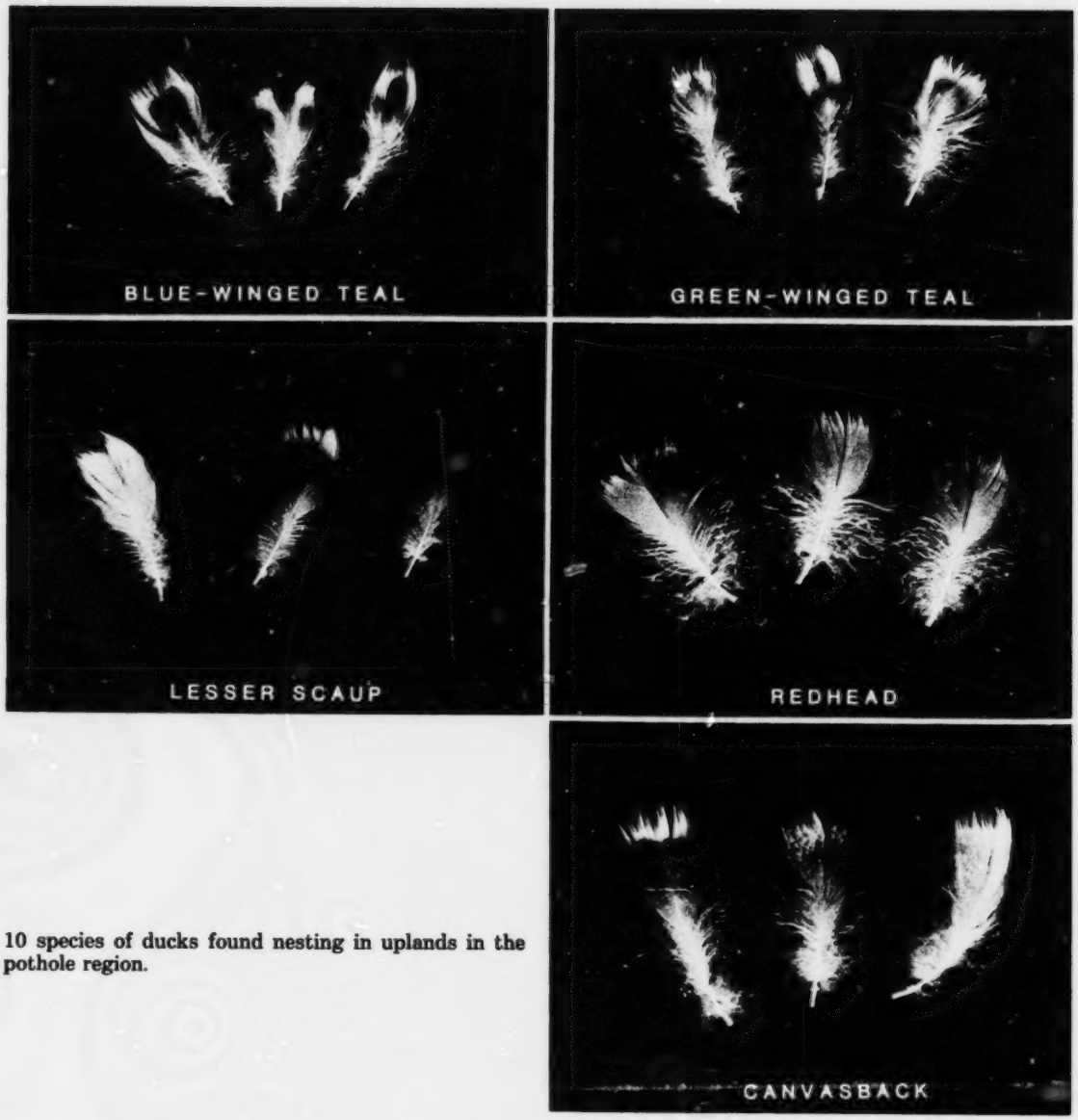


Fig. A-1. Examples of distinguishing breast feathers of prairie

BEST COPY AVAILABLE



10 species of ducks found nesting in uplands in the pothole region.

BEST COPY AVAILABLE

feather has a large brown spot, almost in the center, surrounded by a light tan or cinnamon margin. Down feathers are brown with a relatively small white area in the center. The eggs are buff with a greenish tinge and are slightly larger than teal eggs but smaller than those of the northern pintail, gadwall, and American wigeon.

Gadwall and American Wigeon

Characteristic breast feathers of gadwalls and American wigeons have two colors—light brown and tan or whitish tan. It is not uncommon, however, to find feathers that are all white or light tan with little tonal variation. When present, the central light brown does not extend to the tip. Several characteristics distinguish the two species: (1) the shape of the feather tends to be more oval for the gadwall and more rectangular for the wigeon, (2) the light-colored tip is proportionally wider on wigeon feathers, and (3) the demarcation between the light-colored feather tip and the darker basal area is curved on gadwall feathers but tends to be straighter on wigeon feathers. Broley (1950) described the demarcation line on breast feathers as curved for both species, but our observations have indicated otherwise.

Gadwall down feathers are dark with moderately white frosting on the tips. Wigeon down feathers are very dark, often nearly black, with conspicuously frosted tips. The relatively large eggs of gadwalls and wigeons are creamy white to pale olive buff.

Blue-winged Teal

The coloration and pattern of breast feathers vary. Some feathers have brown centers extending toward the base and contrasting light tan tips and edges. Other variations include feathers that tend to be light tan with several brown spots. Eggs are a creamy tan with very little variation among nests.

Green-winged Teal

The down and breast feathers are very small. Breast feathers tend to have brown centers with light tan edges but are more rectangular than those of blue-winged teal. Nest bowls are smaller than those of the other species described. Green-winged teal eggs appear slightly smaller than blue-winged teal eggs and are creamy white to olive buff.

Lesser Scaup

This species has very dark brown rectangular breast feathers with tan tips. Down feathers are black with very small white centers. Lesser scaup eggs are dark olive buff and are about the same size as mallard eggs, but are smaller than the eggs of redheads or canvasbacks.

Redhead

Breast feathers are brownish gray with a white distal edge. Redhead nests can easily be identified by the pure white down. Redheads usually nest over water, but upland nests may be found.

Canvasback

Breast feathers are light grayish brown with a tan edge. Canvasback and redhead breast feathers are similar, but canvasback down is gray. Although canvasbacks almost always nest over water, nests have been found in upland cover. Eggs of canvasbacks and redheads are large and vary from buff to grayish white.

Key to Down and Breast Feathers

The following key was adapted from Broley (1950). The number of species was reduced from 24 in the original key to 8 that commonly nest in upland habitats in the prairie pothole region, plus the redhead and canvasback that occasionally nest in upland cover.

1. Down wholly white ..... redhead
   Down not wholly white 2
2. Vane of breast feathers mainly white (white at distal end; basal downy portion light grayish beige) ..... green-winged teal
   Vane of breast feather not mainly white .. 3
3. Vane of breast feather dusky with definite light-terminal band and no other markings 4
   Vane of breast feather with conspicuous markings irrespective of tip characteristics 7
4. Total shaft of breast feather dusky ..... lesser scaup
   Proximal third of shaft of breast feather light; distal portion darker 5

BEST COPY AVAILABLE

5. Demarcation of dark areas and light tip of breast feather vane a fairly straight transverse line; down feather with inconspicuous light tips ..... canvasback
   Line of color demarcation decidedly curved 6
6. Dark area of breast feather mottled; down feather with very conspicuous (white) tips .. .. American wigeon
   Dark area of breast feathers darkest in center; down feather with inconspicuous white tips ..... gadwall
7. Vane of breast feather with alternating bars or a dark triangular area ..... mallard
   Vane of breast feather with conspicuous dark central area surrounded on at least three sides with a light marginal area 8
8. Vane of breast feather with dark circular subterminal area ..... northern shoveler
   Vane of breast feather with dark elongated subterminal area 9
9. Down feather with conspicuous white "center" and dark tips; proximal portion of breast feather very light ..... blue-winged teal
   Down feather with inconspicuous white "center"; down feathers appear (in bulk) almost evenly colored throughout; no white in vane of breast feather ..... northern pintail

Appendix B

Instructions for Recording Data and Calculating Nest Success

Glossary

Nest. A scrape or bowl containing one or more eggs. The terms "nest" and "clutch" are often used interchangeably in this and other duck nesting study reports. Only nests tended by hens (not destroyed or abandoned) when found are used to compute nest success by the methods described.

Age when Found. Number of eggs plus incubation stage in days. (Assume that one egg is laid each day.)

Exposure Days. The number of days a clutch of eggs is under observation and vulnerable to loss to predators or other decimating factors.

Full Clutch. Clutch size of incubated nests that have no history of destroyed or missing eggs.

Mean Age at Hatching. Mean clutch size plus mean incubation term in days.

Terminated Nests. Nests, successful or unsuccessful, no longer tended by a hen.

Nest Fate. The success or failure of a nesting attempt.

Abandoned. Intact clutches that are deserted by the hen. True abandonment rates are difficult to estimate because some untended clutches result from the death or injury of hens and some abandoned clutches are destroyed before their true fate can be determined. Abandoned clutches (other than those abandoned because of investigator disturbance on the day found) are combined with destroyed clutches to compute survival rates.

Destroyed. A nest in which one or more eggs are missing or destroyed and none hatched.

Fate Unknown. The fate of the clutch was not determined because of inadequate evidence at the nest site or because the nest was not revisited.

Nonviable. All eggs are infertile, addled, or contain dead embryos.

Successful. One or more eggs hatched even if young are found dead at nest sites.

Nest Success. The probability that a nesting attempt will result in the production of one or more ducklings, as opposed to hen success—the probability that a hen will succeed in hatching at least one duckling in one or more nesting attempts.

Mayfield Method for Computing Nest Success. A method that uses the interval during which a nest is under observation and exposed to decimating factors (*see Exposure Days*).

Shortcut Method for Computing Nest Success. A quick method for obtaining preliminary results or for checking calculations used for the Mayfield estimator.

Traditional Method for Computing Nest Success. The number of nests in which one or more eggs hatched divided by the total number of nests of known fate that were found; *reported as apparent nest success.* Estimates by this method are almost always extremely biased.

Sample Field Form for Recording Nesting Data

The sample Nest Record (Fig. B-1) contains space for entering the data necessary for computating nest success rates, and supplementary data on vegetation at the nest site and the fate of hens and eggs. Some investigators will need other data to meet the objectives of their studies. If so, additional data can be systematically recorded on a supplementary form cross-referenced to the basic record described here.

A computer program is used at Northern Prairie Wildlife Research Center to calculate exposure days for each clutch and to generate tables of clutch survival for such variables as species, study area, and habitat. The Nest Record was designed to facilitate direct computation of exposure days by those who want to process small batches of data without a computer.

Columns 2-19 are used for data control, columns 27-47 are used to compute nest success with a computer, and columns 20-26 and 48-51 are used to record supplementary data on the nest site, hen mortality, unhatched eggs, and parasitism. Uncoded space is provided to record observations made at each visit to the nest (Nest Visitation Record) and for calculating exposure days when a computer is not used. Entries are made in columns 2-27 on the day the nest is discovered. Data in the

BEST COPY AVAILABLE

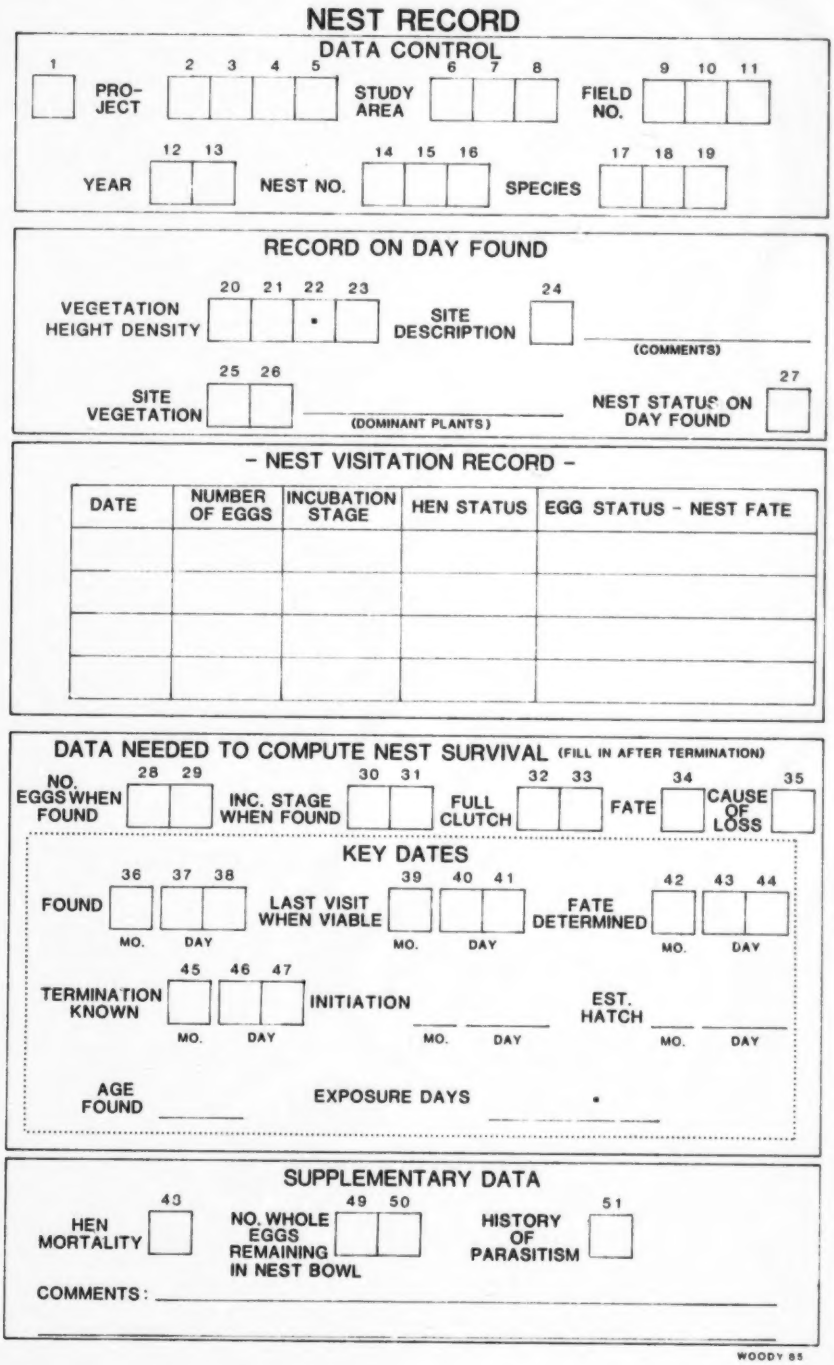


Fig. B-1. Sample nest record.

BEST COPY AVAILABLE

Nest Visitation Record are used to complete columns 28–51 after the last visit to the nest. Instructions for making entries needed to compute nest success (columns 27–47) follow.

Col. 27 **Nest Status on Day Found:** Nests coded greater than 0 are usually not used to compute survival rates. Nesting attempts disrupted by investigators after the first visit may be used in nest survival computations.

0 Normal
1 Eggs destroyed or hen injured or killed by investigators
2 Some eggs cracked or broken by investigators
3 Any other major disturbance by searchers that would jeopardize nest survival
4 Nest abandoned because of investigator disturbance on day found; *determined on second visit*
5 Partially destroyed when found
6 Terminated when found
7 Parasite eggs present when found

Cols. 28–29 **Number of Eggs When Found:** Record number of whole eggs. If nest contains parasite eggs, record only the number of eggs of host species.

Cols. 30–31 **Incubation Stage When Found:**

nn Number of days incubated (00 = laying stage)
44 Pipping
55 Hatched (young in nest)
77 Nesting attempt terminated when found
88 Unknown
99 All eggs addled or contained dead embryos

Cols. 32–33 **Full Clutch:** If nest was not observed during incubation or has a history of parasitism or destroyed or missing eggs, code • (dot) in Col. 33. Do not assume Full Clutch from broken eggs or membranes in terminated nests.

Col. 34 **Fate:**

1 Successful
2 Abandoned—if abandonment was caused by observer on the day the nest was found, code 4 in Col. 27
3 Destroyed
4 Nonviable eggs
5 Unknown

Col. 35 **Cause of Loss:** Data in this column are not used to estimate nest success therefore codes are not presented.

Cols. 36–38 **Date Found:**

Cols. 39–41 **Date of Last Visit on Which Nest Was Still Viable:** Same as Date Found when nest was terminated between the first and second visit, date of second visit when the nest was terminated between second and third visit, etc. May be left blank if nesting attempt was successful.

Cols. 42–44 **Date Fate Determined:** Usually the last visit to the nest. Code • (dot) in Col. 44 if fate not determined, e.g., if nest could not be relocated.

Cols. 45–47 **Date of Termination Known:** For some nests the exact day of termination is known. For example, hatched young were observed in the nest; the nest was destroyed or abandoned because of investigator activity; the date the nest was abandoned was determined from the increase in number of eggs, advance in stage of incubation, or both of these; the date of a destructive event such as a storm or tillage operation is known. Do not confuse with estimated hatch date. Leave blank if unknown.

Computation of Nest Success

Data in columns 27–47 are sufficient for calculating nest success rates by computer. If a computer is not used, complete the following in the uncoded section of the Nest Record and calculate nest success as described on page 24.

Age When Found: *Number of Eggs When Found* plus *Incubation Stage When Found.* If nest is found when eggs are pipping (Cols. 30–31 = 44),

BEST COPY AVAILABLE

Table B-1. *Mean values for clutch sizes, incubation terms, and age of clutches at hatching.*

Species	A.O.U. Number[a]	Clutch size[b]	Incubation term (days)	Age of clutches at hatching (days)
Mallard	132	9	26	35
Gadwall	135	10	25	35
American wigeon	137	8	25	33
Green-winged teal	139	9	24	33
Blue-winged teal	140	10	24	34
Northern shoveler	142	10	24	34
Northern pintail	143	8	24	32
Redhead	146	10	25	35
Canvasback	147	10	26	36
Lesser scaup	149	9	26	35

[a] American Ornithologists' Union (1983).
[b] Clutch sizes may vary seasonally or yearly. Investigators may wish to calculate means from their samples.

use average incubation term minus 1 for incubation stage. A nest record is not used to calculate nest success if the age at discovery is unknown.

Estimated Initiation Date: *Date Found* minus *Age When Found.*

Estimated Hatch Date: *Initiation Date* plus *Full Clutch* plus *Average Incubation Term* (Table B-1). Use mean clutch size (Table B-1) if Full Clutch is not known. (Exception: If eggs are observed while pipping, the estimated hatch date is the following day.)

Exposure Days: Exclude abnormal nests (Col. 27 > 0) and those with Age When Found unknown; then determine exposure days as follows:

Termination date known (Table B-2, nest 1):
Exposure = *Known Termination Date* minus *Date Found.*
Termination date unknown:
Nesting attempt successful (Table B-2, nest 2):
Exposure = *Estimated Hatch Date* minus *Date Found.*
Fate of nest is unknown (Table B-2, nest 3):
Exposure = *Last Visit Date When Clutch Was Viable* minus *Date Found.*
Nesting attempt unsuccessful (Table B-2, nests 4-7):
Exposure = *Known Exposure* plus *Probable Exposure* where
Known Exposure = *Last Date Nest Viable* minus *Date Found* and

Table B-2. *Computation of exposure days for nests with different survival and visitation intervals.*[a]

Nest number	Julian date: Date Found[b]	Last date nest viable[c]	Fate determined[d]	Termination known[e]	Estimated hatch[f]	Exposure days: Known	Probable	Total	Fate
1	*135*	135	150	*149*	152	14	0	14.0	destroyed
2	*135*		156		*152*	17	0	17.0	successful
3	*135*	*142*	-		152	7	0	7.0	unknown
4	*135*	*142*	*149*		152	7	3.5	10.5	destroyed
5	*135*	*135*	*142*		152	0	3.5	3.5	destroyed
6	*135*	*149*	156		*152*	14	1.5	15.5	abandoned
7	*135*	*135*	156		*152*	0	6.8	6.8	destroyed

[a] Dates used in computations are in italics.
[b] All examples were found at 18 days of age on 15 May (135 Julian).
[c] Date of last visit to nest site when the clutch was viable (not destroyed or abandoned).
[d] Date of visit when fate of clutch was determined.
[e] Date when eggs hatched or clutch was abandoned or destroyed—usually unknown.
[f] Initiation date plus mean age of mallard nests at hatching.

BEST COPY AVAILABLE

Probable Exposure = half the interval between *Last Date Nest Viable* and the lesser of *Date Fate Determined* and *Estimated Hatch Date* (Multiply by 0.4 instead of 0.5 if this interval is > 14 days; table B–2, nest 7).

Nest Success: Two methods for calculating nest success—the Mayfield method and a shortcut method—are described. Examples of calculations by both methods are presented in Table B–3.

Mayfield exposure method.

Usable records. Nest survival rates are calculated from nests for which exposure days are available.

Number of nesting attempts that failed (N_u). Tally number of nesting attempts that failed (Col. 34 = 2, 3, or 4). Exception: Do not include losses due to investigator disturbance that occurred after the first visit, but do include exposure days.

Total exposure days (E). Sum of exposure days for all usable records.

Mean age at hatching (h). From Table B–1.

Estimated nest success (P_2). Calculate as in Table B–3.

Shortcut method.

Usable records. Exclude abnormal nests (Col. 27 > 0) and those with unknown fate and unknown age when found.

Apparent nest success (P_1). Number of successful nests divided by all usable nests.

Mean age at hatching (h). From Table B–1.

Mean age of nests when found (f). Calculate mean age of nests when found from usable nest records.

Estimated nest success rate (P_3). Calculate as in Table B–3.

Table B–3. *Three methods for calculating nest success (from unpublished mallard nesting data, NPWRC).*

Nest data

N_s = number of successful clutches (41)
N_u = number of unsuccessful clutches (89)
E = total exposure days (1,966)
h = mean age of clutches at hatching (35 days)
f = mean age of clutches when found (8.9)

Estimation methods

1) Apparent nest success (P_1)

$$P_1 = N_s/(N_s + N_u) = 41/(130) = 0.315$$

2) Mayfield exposure method (P_2)

$$P_2 = (1 - N_u/E)^h = (1 - 89/1{,}966)^{35} = 0.198$$

3) Shortcut method (P_3)

$$P_3 = [P_1^{1/(35-8.9)}]^{35} = [0.315^{1/(35-8.9)}]^{35} = 0.212$$

☆ U.S. Government Printing Office: 1986—676-205/40002

Klett, Albert T., Harold F. Duebbert, Craig A. Faanes, and Kenneth F. Higgins. **Techniques for Studying Nest Success of Ducks in Upland Habitats in the Prairie Pothole Region.** U.S. Fish Wildl. Serv., Resour. Publ. 158. 24 pp. 1986.

Procedures for conducting nesting studies of upland nesting ducks in the prairie pothole region are described. Techniques are addressed for finding nests with drags towed by vehicles, recording essential data, candling eggs in the field, determining fate of clutches, and identifying species from evidence at nests. Two methods are described for calculating clutch survival.

Key Words: nesting study techniques; upland nesting ducks; prairie pothole region.

Klett, Albert T., Harold F. Duebbert, Craig A. Faanes, and Kenneth F. Higgins. **Techniques for Studying Nest Success of Ducks in Upland Habitats in the Prairie Pothole Region.** U.S. Fish Wildl. Serv., Resour. Publ. 158. 24 pp. 1986.

Procedures for conducting nesting studies of upland nesting ducks in the prairie pothole region are described. Techniques are addressed for finding nests with drags towed by vehicles, recording essential data, candling eggs in the field, determining fate of clutches, and identifying species from evidence at nests. Two methods are described for calculating clutch survival.

Key Words: nesting study techniques; upland nesting ducks; prairie pothole region.

Klett, Albert T., Harold F. Duebbert, Craig A. Faanes, and Kenneth F. Higgins. **Techniques for Studying Nest Success of Ducks in Upland Habitats in the Prairie Pothole Region.** U.S. Fish Wildl. Serv., Resour. Publ. 158. 24 pp. 1986.

Procedures for conducting nesting studies of upland nesting ducks in the prairie pothole region are described. Techniques are addressed for finding nests with drags towed by vehicles, recording essential data, candling eggs in the field, determining fate of clutches, and identifying species from evidence at nests. Two methods are described for calculating clutch survival.

Key Words: nesting study techniques; upland nesting ducks; prairie pothole region.

Klett, Albert T., Harold F. Duebbert, Craig A. Faanes, and Kenneth F. Higgins. **Techniques for Studying Nest Success of Ducks in Upland Habitats in the Prairie Pothole Region.** U.S. Fish Wildl. Serv., Resour. Publ. 158. 24 pp. 1986.

Procedures for conducting nesting studies of upland nesting ducks in the prairie pothole region are described. Techniques are addressed for finding nests with drags towed by vehicles, recording essential data, candling eggs in the field, determining fate of clutches, and identifying species from evidence at nests. Two methods are described for calculating clutch survival.

Key Words: nesting study techniques; upland nesting ducks; prairie pothole region.

A list of current *Resource Publications* follows.

143. House Bat Management, by Arthur M. Greenhall. 1982. 30 pp.
144. Avian Use of Sheyenne Lake and Associated Habitats in Central North Dakota, by Craig A. Faanes. 1982. 24 pp.
145. Wolf Depredation on Livestock in Minnesota, by Steven H. Fritts. 1982. 11 pp.
146. Effects of the 1976 Seney National Wildlife Refuge Wildfire on Wildlife and Wildlife Habitats, compiled by Stanley H. Anderson. 1982. 28 pp.
147. Population Ecology of the Mallard. VII. Distribution and Derivation of the Harvest, by Robert E. Munro and Charles F. Kimball. 1982. 126 pp.
148. Management of Seasonally Flooded Impoundments for Wildlife, by Leigh H. Fredrickson and T. Scott Taylor. 1982. 19 pp.
149. Mitigation and Enhancement Techniques for the Upper Mississippi River System and Other Larger River Systems, by Rosalie A. Schnick, John M. Morton, Jeffrey C. Mochalski, and Jonathan T. Beall. 1982. 714 pp.
150. Microscopic Anatomy of Salmonids: An Atlas, by William T. Yasutake and Joseph H. Wales. 1983.
151. Avian Use of Forest Habitats in the Pembina Hills of Northeastern North Dakota, by Craig A. Faanes and Jonathan M. Andrew. 1983. 24 pp.
152. National Pesticide Monitoring Program: Organochlorine Residues in Freshwater Fish, by Christopher J. Schmitt, Michael A. Ribick, J. Larry Ludke and Thomas M. May. 1983. 62 pp.
153. Handbook of Toxicity of Pesticides to Wildlife, by Rick H. Hudson, Richard K. Tucker and M. A. Haegele. 1984. 97 pp.
154. Nonconsumptive Use of Wildlife in the United States, by William W. Shaw and William R. Mangun. 1984. 20 pp.
155. Ecology and Management of the Bullfrog, by R. Bruce Bury and Jill A. Whelan 1984. 23 pp.
156. Statistical Inference From Band Recovery Data—A Handbook, by Cavell Brownie, David R. Anderson, Kenneth P. Burnham, and Douglas S. Robson. 1985.
157. The Breeding Bird Survey: Its First Fifteen Years, 1965–1979, by Chandler S. Robbins, Danny Bystrak and Paul H. Giessler. 1986. 196 pp.

NOTE: Use of trade names does not imply U.S. Government endorsement of commercial products.

BEST COPY AVAILABLE

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
OFFICE OF INFORMATION TRANSFER
EDITORIAL SECTION
AYLESWORTH HALL, CSU
FORT COLLINS, COLORADO 80523

THIRD-CLASS MAIL
POSTAGE AND FEES PAID
U.S. DEPARTMENT OF THE INTERIOR
PERMIT No. G-77

NOTE: Mailing lists are computerized. Please return address label with change of address.

BEST COPY AVAILABLE